"An Investigation of Some Connecting Links in the Disintegration Series of Uranium and Thorium"

and Other Papers

John A. Cranston.

ProQuest LLC.
789 East Eisenhower Parkway
P.O. Box 1346
Ann Arbor, MI 48106 – 1346

Preface.

1. This book is a record of original work that I have undertaken under the supervision of Professor F. Soddy M.A. F.R.S. in the Universities of Glasgow and Aberdeen since my graduation as B.Sc. in Glasgow University in 1912.

2. It was interrupted during the period March 1915 to September 1919 when I was a commissioned officer in His Majesty's Forces. I was in the Special Brigade, R.E. [Gas Services] three and a half years of this time, two and a half years of which were spent in France. I was one of the first chemists to be employed on special duties and so had much pioneer work to do ~~[illegible]~~ with regard to the training of our troops in antigas measures, in the collection of samples of German gases, and in intelligence work about German Gas tactics. During this period I passed over 50,000 of our troops through gas to give them confidence in their protective appliances and gave over 1000 technical lectures on defence against gas.

3. I am now employed as Lecturer in Physical Chemistry at the Royal Technical College, Glasgow.

4. The main subject of this thesis is divided into three parts as the researches deal with three different portions of the radio active series,

Part I. "The Growth of Radio thorium from Meso thorium 2", which proved that these bodies are formed in direct sequence and thus linked up two portions of the thorium series;
Part II. "The Atomic Weight of Iodine" which showed that a certain quantity of iodine present in Ceylon thorite did not appreciably differ in atomic weight from ordinary Iodine and therefore could not be the missing Group VII member in the 4th long series of the Periodic Table;
Part III "The Parent of Actinium", which resulted in the discovery of a new element in pitchblende which produced Actinium after lapse of time.

5. The first part of these researches was published in the Philosophical Magazine for May 1913, the last, together with researches by Professor Soddy on the same subject, in the Proceedings of the Royal Society A. Vol. 94. 1918. Copies of these are enclosed herewith. It is hoped to publish the second shortly.

6. The additional papers are,

2. "The Ionisation Produced at an External Point by a Sphere of Uniformly Radio active Matter."
3. "The Acquired Radio-activity of Diamonds."
4. "The Separation of Actinium and Lanthanum."

---

9. 1. 20.

John Arnold Cranston.
The Royal Technical College
Glasgow.

Contents.

Part. I.

The Growth of Radio-thorium from Meso-thorium 2.

Object.

The object of this research was to establish whether or not there exists an intermediate body between mesothorium 2 and radio-thorium.

General Method.

This was attained by observing the growth of α-activity from a quantity of pure mesothorium 2.

Theory.

A theoretical curve for this growth was calculated making the following assumptions :-

(1) That mesothorium 2 gives no α rays
(2) That mesothorium 2 disintegrates directly into radio-thorium.
(3) That during the course of an experiment (1 month) the amount of radio thorium present does not decrease appreciably by its own disintegration.
(4) That thorium X, thorium emanation, and thorium A disintegrate together.
(5) That thorium B and thorium C disintegrate together.

Let B, C and E denote the amounts of Radio-thorium, Thorium X and Thorium C present at time t, and B_∞ the amount of Radio-thorium formed when the meso-thorium has completely decayed.

Let the radio active constants of Meso Th. 2, Ra Th, Th X Th B + Th C. be denoted by λ_1, λ_2, λ_3, λ_4 and λ_5 respectively

Then the amounts B, C, and E can be calculated in terms of the radio active constants as follows:

$$\frac{B}{B_\infty} = 1 - e^{-\lambda_1 t}$$

$$B = B_\infty \left[1 - e^{-\lambda_1 t}\right] \qquad \text{..... (1)}$$

$$\frac{dC}{dt} = \lambda_2 B - \lambda_3 C$$

$$= \lambda_2 B_\infty \left[1 - e^{-\lambda_1 t}\right] - \lambda_3 C$$

$$\frac{dC}{dt} e^{\lambda_3 t} + \lambda_3 C e^{\lambda_3 t} = \lambda_2 B_\infty e^{\lambda_3 t} - \lambda_2 B_\infty e^{\overline{\lambda_3 - \lambda_1} \cdot t}$$

$$C e^{\lambda_3 t} = \frac{\lambda_2}{\lambda_3} B_\infty e^{\lambda_3 t} - \frac{\lambda_2}{\overline{\lambda_3 - \lambda_1}} B_\infty e^{\overline{\lambda_3 - \lambda_1} \cdot t} + K$$

$$K = \frac{\lambda_2}{\lambda_3 - \lambda_1} B_\infty - \frac{\lambda_2}{\lambda_3} B_\infty$$

$$= \frac{\lambda_2 \lambda_1}{\lambda_3 (\lambda_3 - \lambda_1)} B_\infty$$

$$\therefore C = \lambda_2 B_\infty \left[\frac{1}{\lambda_3} - \frac{e^{-\lambda_1 t}}{\lambda_3 - \lambda_1} + \frac{\lambda_1 e^{-\lambda_3 t}}{\lambda_3 (\lambda_3 - \lambda_1)}\right]$$

$$= \frac{\lambda_2 B_\infty}{\lambda_3} \left[1 - \frac{\lambda_3}{\lambda_3 - \lambda_1} e^{-\lambda_1 t} + \frac{\lambda_1}{\lambda_3 - \lambda_1} e^{-\lambda_3 t}\right] \qquad \text{..... (2)}$$

$\frac{dD}{dt} = \lambda_3 C - \lambda_4 D$ where D is the amount of Thorium B present after time "t". It does not contribute to the α activity, but it is necessary to find D in terms of B_∞ and the radio active constants before E can be determined.

$$\therefore \frac{dD}{dt} + \lambda_4 D = \lambda_3 C$$

$$\therefore \quad \frac{d\,D}{dt} + \lambda_4 D = \frac{\lambda_2 B_\infty}{\lambda_3 - \lambda_1}\left[\lambda_3 - \lambda_1 - \lambda_3 e^{-\lambda_1 t} + \lambda_1 e^{-\lambda_3 t}\right].$$

$$\therefore \quad \frac{d}{dt} D e^{\lambda_4 t} = \frac{\lambda_2 B_\infty}{\lambda_3 - \lambda_1}\left[\overline{\lambda_3 - \lambda_1}\, e^{\lambda_4 t} - \lambda_3 e^{\overline{\lambda_4 - \lambda_1}.t} + \lambda_1 e^{\overline{\lambda_4 - \lambda_3}.t}\right]$$

$$\therefore \quad D e^{\lambda_4 t} = \frac{\lambda_2 B_\infty}{\lambda_3 - \lambda_1}\left[\frac{\lambda_3 - \lambda_1}{\lambda_4} e^{\lambda_4 t} - \frac{\lambda_3}{\lambda_4 - \lambda_1} e^{\overline{\lambda_4 - \lambda_1}.t} + \frac{\lambda_1}{\lambda_4 - \lambda_3} e^{\overline{\lambda_4 - \lambda_3}.t}\right]$$

$$- \frac{\lambda_2 B_\infty}{\lambda_3 - \lambda_1}\left[\frac{\lambda_3 - \lambda_1}{\lambda_4} - \frac{\lambda_3}{\lambda_4 - \lambda_1} + \frac{\lambda_1}{\lambda_4 - \lambda_3}\right]$$

Inserting the values of the radio active constants as $(\text{hours})^{-1}$ we get.

$$D = \frac{\lambda_2 B_\infty}{-.1046}\left[-1.600 + .166\, e^{-\lambda_1 t} + 1.951^{-\lambda_3 t}\right] + 4.94\, \lambda_2 B_\infty e^{-\lambda_4 t} \quad \ldots\ldots (3)$$

$$d\,E = \lambda_4 D - \lambda_5 E.$$

$$\frac{dE}{dt} + \lambda_5 E = \lambda_4 . D$$

$$= \lambda_4 . \lambda_2 B_\infty \left[\frac{1}{.1046}\left\{1.600 - .166\, e^{-\lambda_1 t} - 1.951^{-\lambda_3 t}\right\} + 4.94\, e^{-\lambda_4 t}\right]$$

$$= \lambda_2 B_\infty \left[1 - .104\, e^{-\lambda_1 t} - 1.219\, e^{-\lambda_3 t} + .323\, e^{-\lambda_4 t}\right]$$

$$\therefore \frac{d}{dt} E e^{\lambda_5 t} = \lambda_2 B_\infty \left[e^{\lambda_5 t} - .104\, e^{\overline{\lambda_5 - \lambda_1}.t} - 1.219\, e^{\overline{\lambda_5 - \lambda_3}.t} + .323\, e^{\overline{\lambda_5 - \lambda_4}.t}\right]$$

$$\therefore \lambda_5 E = \lambda_2 B_\infty \left[1 - \frac{\lambda_5}{\lambda_5 - \lambda_1} .104\, e^{\overline{\lambda_5 - \lambda_1}.t} - \frac{\lambda_5}{\lambda_5 - \lambda_3} 1.219\, e^{\overline{\lambda_5 - \lambda_3}.t} + \frac{\lambda_5}{\lambda_5 - \lambda_4} .323\, e^{-\overline{\lambda_5 - \lambda_4}.t}\right.$$

$$\left. - \left(\frac{1}{\lambda_5} - \frac{.104}{\lambda_5 - \lambda_1} - \frac{1.219}{\lambda_5 - \lambda_3} + \frac{.323}{\lambda_5 - \lambda_4}\right) e^{-\lambda_5 t} \times \lambda_5 .\right] \quad \ldots\ldots (4).$$

We have now got expressions denoting the amounts of B, C + E present at time t. To get a theoretical ionization curve the percentage of the total ionization contributed by one α ray of each substance is required.

This was got from Geiger's formula:

If a distance x along the range, the ionization i is

$$i = a(R - x)^{\frac{1}{3}}$$ where a is a constant

Then $I_{1.5}^{R} = k(R - 1.5)^{\frac{2}{3}}$. The ionization is taken from 1.5 cms to the end of the Range, this correction 1.5 cms. being the equivalent in air of the matter the α rays had to traverse before entering the particular magnet-electroscope that was used.

This gave for the series.

Radio thorium	14.2	
Thorium X	16.5	58.3 *
Th Emanation	19.6	
Th. A	22.2	
Th C	6.0	27.5 *
Th C'	21.5	
	100.0	

* From assumptions stated on page 5, these two groups are calculated as disintegrating as two substances only.

The α radiation is thus proportional to

$$14.2\,\lambda_2 B + 58.3\,\lambda_3 C + 27.5\,\lambda_5 E$$

Inserting the values of B, C + E already found in Equations (1), (2) and (4). the total Ionization I is given by

$$I = k\left[14.2\,\lambda_2 B_\infty (1-e^{-\lambda_1 t}) + 58.3\,\lambda_2 B_\infty \left(1 - \frac{\lambda_3}{\lambda_3-\lambda_1} e^{-\lambda t} + \frac{\lambda_1}{\lambda_3-\lambda_1} e^{-\lambda_3 t}\right)\right.$$

$$+ 5.6\,27.5\,\lambda_2 B_\infty \left(1 - \frac{\lambda_5}{\lambda_5-\lambda_1} .104\, e^{\overline{\lambda_5-\lambda_1}\,t} - \frac{\lambda_5}{\lambda_5-\lambda_3} 1.2.19\, e^{\overline{\lambda_5-\lambda_3}\,t}\right.$$

$$\left.\left. + \frac{\lambda_5}{\lambda_5-\lambda_4} .323^{\overline{\lambda_5-\lambda_4}\,t} - \lambda_5 e^{-\lambda_5 t}\left\{\frac{1}{\lambda_5} - \frac{1.04}{\lambda_5-\lambda_1} - \frac{1.219}{\lambda_5-\lambda_3} + \frac{.323}{\lambda_5-\lambda_4}\right\}\right)\right]$$

$$= k'\left[57.6 - 7.6\, e^{-\lambda_1 t} - 55.6\, e^{-\lambda_3 t} + 5.6\, e^{-\lambda_4 t}\right]$$

where k' is a constant.

Taking $k' = 1$, the relative values of the ionization for different values of "t" were calculated as follows:

t (in hours)	I	t (in hours)	I
1	1.01	15	8.86
2	1.78	20	10.79
3	2.63	25	12.52
4	3.39	30	14.18
5	3.81	50	20.11
6	4.52	75	26.67
7	5.07	100	32.14
8	5.70	200	45.93
9	6.19	300	52.24
10	6.64	400	55.14
11	7.15	500	56.47
12	7.57	700	57.36
13	7.98	∞	57.60

Preparation of a Film of Pure Mesothorium 2.

The first chemical problem was to obtain a film of pure Mesothorium 2 on a tray so that the increase of the α activity with time could be observed.

A convenient and continuous source of Meso. thorium 2 was obtained from a solution of mesothorium 1 associated with about 100 grams of barium chloride.

By adding a few drops of Thorium Nitrate in acid solution and precipitating out the Thorium again with Ammonia, the mesothorium 2, radiothorium, thorium B and thorium C present were removed. The thorium X, being similar to the mesothorium 1 remained in solution and so generated again the post emanation substances. However its parent radio thorium, of comparatively long life, had been removed and so the quantity of thorium X present diminished approximately according to its period 5·35 days.

By repeating the precipitation of Thorium in the main solution every second day for a month the meso thorium 1 solution was made considerably more free from thorium X and subsequent products. The solution was then ready as a source of Mesothorium 2.

A thorium salt was added and thorium hydroxide precipitated out of the solution in the usual way. It was then re-dissolved in the smallest quantity of hydrochloric acid, neutralized and a reagent added that would precipitate out the Thorium and leave the mesothorium

2 in solution.

Various reagents were tried and their value in effecting this separation was found as shown below, the mesothorium 2 being estimated by evaporating the solution to dryness and comparing the β & γ activity with the known original activity - allowing for the decay during the course of the experiment.

Reagent.	Percentage of Meso. thorium 2 separated.
Ammonia	16
Methylamine	11
m. Nitro benzoic Acid	100
Ammonium Hydrazoate	74
Hydrogen Peroxide	100

The Hydrogen Peroxide was chosen as the most convenient reagent. It removed most of the Thorium B and part of the Thorium C.

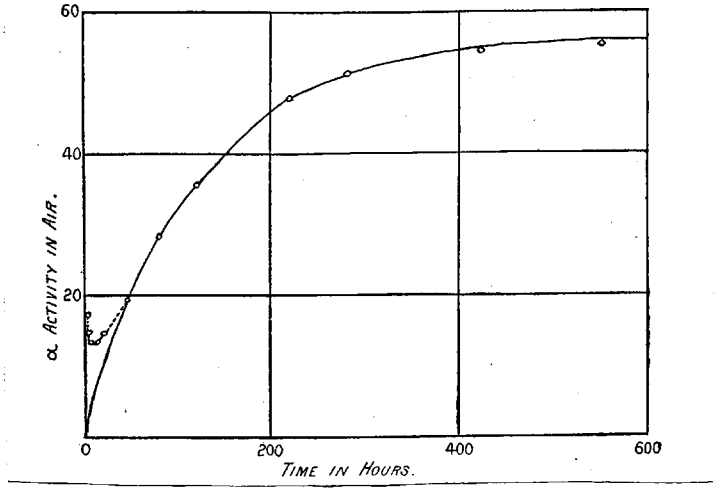
To the solution thus freed from Thorium, an attempt was made to remove all the Thorium B and C by adding lead and bismuth and precipitating them out again with Sulphuretted Hydrogen several times.

The filtrate was then evaporated down to dryness on a silver tray and the ammonium salts were ignited leaving a film of mesothorium 2.

Measurement of the α Activity.

The electroscope used was mounted on a powerful electro-magnet. It had a brass base out of which a slot was cut the size of the tray (7·7 cm × 1·4 cm). A sheet of aluminium foil (thickness ·00035 cm.) covered the slot. The tray when in position below the slot lay between the poles of the electromagnet.

The electroscope was provided with a mica screen which could be slipped over the slot so as to absorb all the α rays without appreciably affecting the β or γ activity. The difference between two measurements made, one with the mica off and one with the mica on (both being made with the magnet on to deflect the β rays) gave the α activity.



The variation of the α activity with time is shown in the figure, experimental points being indicated by the circles. The continuous line is the curve obtained by [illegible]

the data tabulated on page 9.

The scale of the α activities was chosen so that the experimental point 220 hours from the start lay on the theoretical curve.

It was thus seen that, while the curves did not agree for the first few hours, the subsequent close agreement established the fact of the direct growth of radio thorium from the mesothorium 2.

The Initial α activity of the Film of Meso. thorium 2.

The above experiment was repeated in all twenty three times varying the conditions in an attempt to prepare a film of Mesothorium 2 initially quite free from α activity.

Although finally this activity was reduced considerably, no attempt was successful in preparing a film quite free initially.

1. Hydrogen electroscope.

Measurements were made with the electroscope filled with hydrogen. This minimised the effect of the β & γ rays. The α ray ionisation was increased in the ratio 1.7 to 1.

2. Absorption Curves of Initial Activity.

Measurements were made of the absorption coefficient of the α rays. The thickness of two pieces of mica and several sheets of aluminium foil were measured.

Thickness of Mica "A" = .021 mm.

" " " "B" = .016 "

" " Aluminium foil = .0035 " . [Equivalent to .7 cms. air].

The curves obtained are shown in the graphs 5, 6 + 7. (pp. 19-21) They gave for the absorption coefficient $\mu = 250$, indicating that they were probably due to Thorium B and Thorium C.

3. Raising Temperature of Heating.

The Silver tray was replaced by less fusible trays of Quartz and Platinum. These were heated to a white heat in an oxyhydrogen blowpipe in an attempt to volatilise the Thorium B and Thorium C.

Although this reduced the α activity it did not even on prolonged heating get rid of it entirely.

4. Observations with a Spintharioscope.

To find out if this initial activity was due to feebly penetrating γ rays from Mesothorium 2 with a coefficient of absorption of the order of that of α rays, measurements were carried out with a spintharioscope.

The latter was first of all calibrated with the magnet - hydrogen electroscope. It weighed

quantity of Uranium Oxide was dissolved in Nitric Acid and the solution made up to a certain volume. Twenty five ccs. of this solution were evaporated to dryness on a piece of Platinum foil fitted into a quartz boat. This contained 20 mgms. of metallic Uranium Its activity measured by ionisation = 6·0 divisions a minute in air and 11·3 divisions a minute in hydroge

1 gm. of Radium gives 3.4×10^{10} α. particles per second.

1 " " Uranium " $\frac{3.4 \times 10^{10} \times 2000}{5 \times 10^{9}}$ " " "

·02 " " Uranium in equilibrium with Ionium + Radium

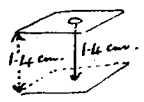
gives $\frac{3.4 \times 10^{10} \times 2000 \times 2.5}{5 \times 10^{9}}$ α. particles per sec.

= 850 α particles per second.

Calculation of the Proportion of these that would come into the field of vision of the microscope.

Area of tray = 1×1.7 sq. cm.

Distance between tray and Zinc Sulphide screen = 1·4 cm.



Surface = $4\pi r^2$

= $4\pi \ 1.4^2$

= 12.5×1.96

= 25 sq. cm.

Diameter of field of vision = 21·5 mm.

Area " " " " = ·8 sq. mm.

Proportion of α rays seen = $\frac{1 \text{ in } 25 \times 100}{\cdot 8}$

= 1 in 3000

Fresh preparations of pure films of Meso-thorium 2 showed that the initial non-deviable easily absorbed activity produced scintillations on a Zinc Sulphide screen of the order expected if the activity were due to α rays.

5. Experiments to Determine the best method of volatilising Thorium B and Thorium C.

A quantity of Thorium B and C giving an initial activity of more than 6000 divisions a minute was heated on a piece of Platinum placed in a quartz boat. After the usual heating to white heat for half an hour the activity was still 80 divisions a minute.

It was then heated in hydrogen to a red heat for 10 minutes and the activity was reduced to 30 divisions a minute.

In two preparations of films of Mesothorium 2, the first heated to white heat in the air the second heated in a quartz furnace to red heat in an atmosphere of Coal gas, the following results were obtained.

Ratio of activities on the β electroscope $= \frac{13.1}{43.5} = .33$

Ratio of β activities in H. on Magnet Electroscope $= \frac{21.7}{66.5} = .32$

Ratio of α activities in Hydrogen " " $= \frac{8.5}{17.5} = .49$.

Thus in the second experiment by heating

the preparation in a reducing atmosphere of coal gas the proportion of α activity was lowered.

Further experiments showed that greatest volatilisation of Thorium B and C occurred when they were heated in an atmosphere of Hydrogen though complete volatilisation was never obtained.

6. Calculation of the no. of atoms of Mesothorium 2 disintegrating with expulsion of α rays on Assumption that all this Initial α Activity was due to Meso. thorium 2.

If Mesothorium 2 disintegrates with the expulsion of α rays, according to the Geiger-Nuttall relationship it should have a range of 4·2 cms. and from a calculation similar to that shown on page 8 of this thesis, the ionisation it would produce would be 16·3% of the total of the rest.

So the mesothorium 2 is present initially pure, the ionisation due to it, if it all gave out α rays would be $\frac{2\cdot 91 \times 365 \times 24}{8\cdot 9} \times \frac{16\cdot 3}{100}$ times the maximum of the curve of activity shown on page 12. [The first fraction denotes the relation of the period of radio thorium to the period of meso thorium 2.]

i.e. Initial activity would be 467 times the final (after 1 month)

But in certain preparations the initial activity was less than $\frac{1}{10}$th the final. Therefore the proportion of Mesothorium 2 atoms disintegrating with the expulsion of an α particle must be less than 2 in 10,000.

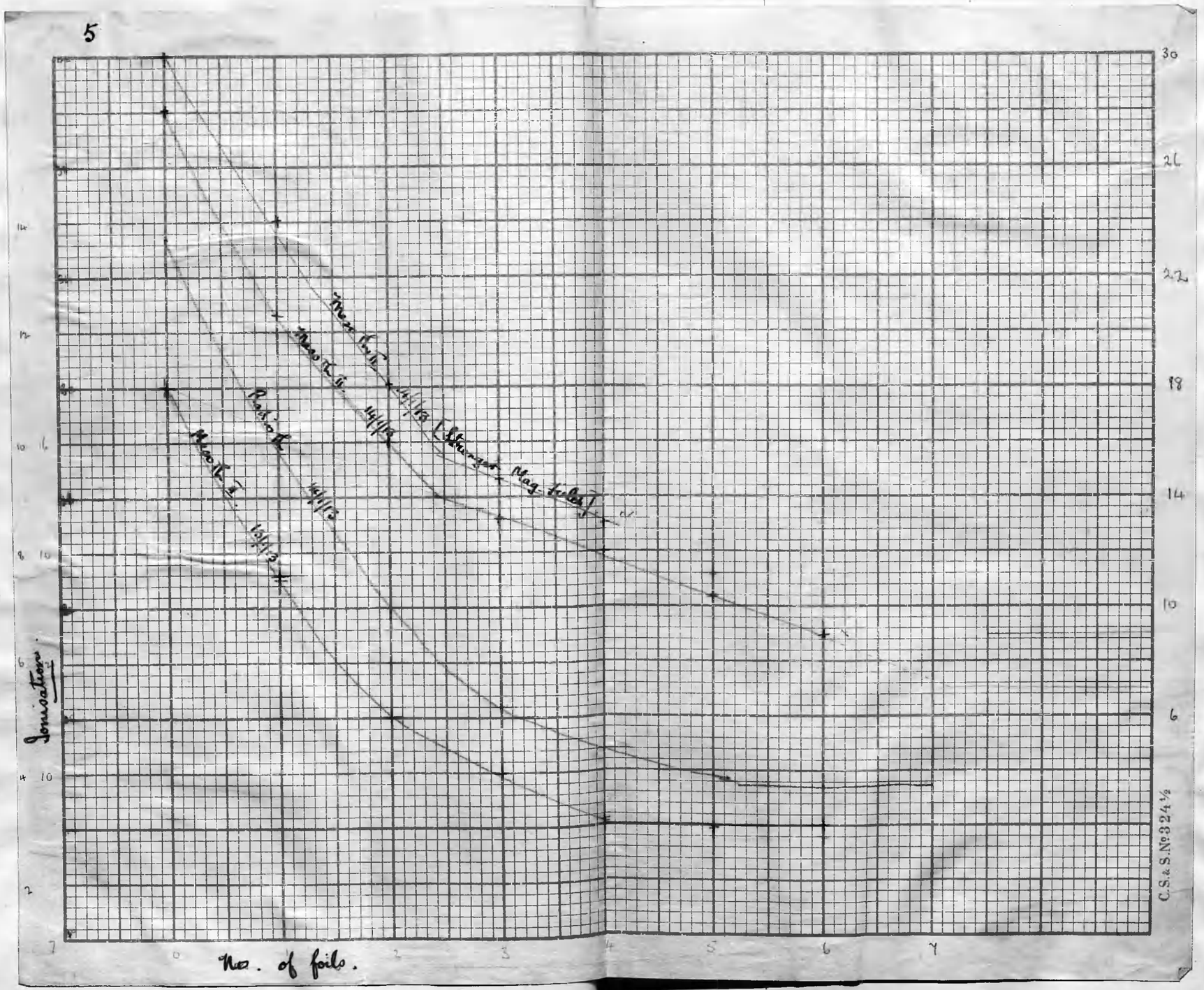
7. Conclusion.

The slight initial activities obtained in various preparations of Meso thorium 2 bore no proportion to the quantity of Meso thorium 2 present; nor did the difference curves (Experimental to theoretical) bear any resemblance to the exponential curve of Mesothorium 2, proving the absence of any α ray from Mesothorium 2.

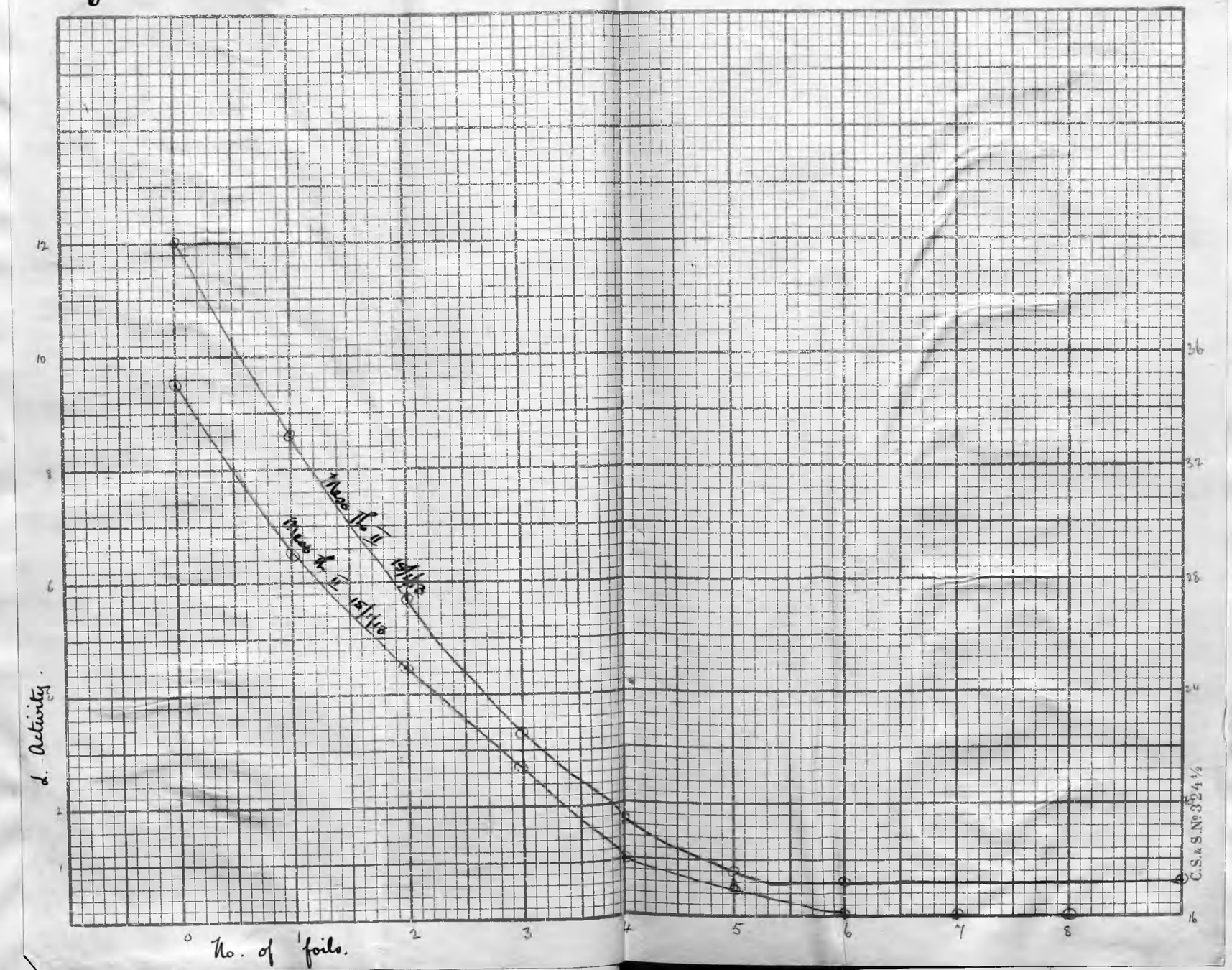
It also proves the absence of any feebly penetrating γ ray having an absorption coefficient similar to that of the α ray.

Special experiments showed the extreme difficulty of volatilising off the last traces of Thorium B and C in the short time available before measurements of the ionisation curve had to be commenced.

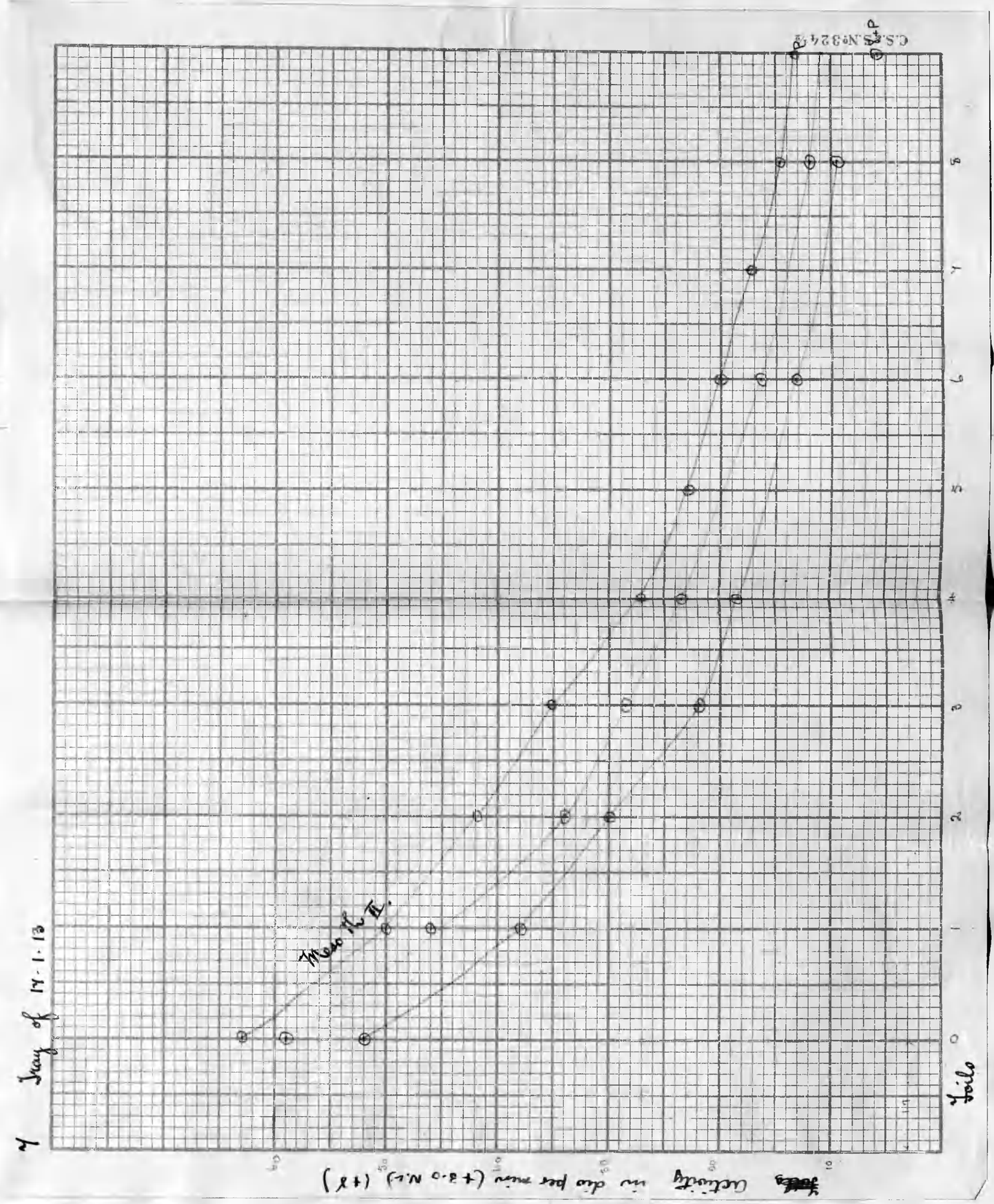
5


Ionisation.
No. of foils.
Mean Kin. 14/1/13
Mean Kin. 14/1/13
Radium E
Mean Kin. 14/1/13
Mean Kin. 14/1/13
Mag. Kicks
30
26
22
18
14
10
6
C.S.& S.No 324½

6


d. Activity.
No. of foils.
Mean No. 1 results
Mean No. 2 results
12
10
8
6
4
2
0
1
2
3
4
5
6
7
8
36
32
28
24
20
16
C.S.& S. No. 324 ½

21.



1 Jany of 14-1-13

Part II

The Atomic Weight of Iodine From Radio active Sources

The Atomic Weight of Iodine in Ceylon Thorite.

The recent researches on the atomic weight of Lead, samples of which have been chosen from Uranium and Thorium minerals, have given values varying over 1½ units, according to the ratio of Uranium to Thorium in the mineral.

This work has suggested that there might be common elements other than Lead present in radio active minerals owing to their generation from Uranium or Thorium. If such an element exists it is possible that its atomic weight may be different from its more common isotope.

The discovery by Soddy of an element in Ceylon Thorite with the chemical properties of Iodine coupled with the fact of the anomalous atomic weight of Iodine suggested that the element might be isotopic with ordinary Iodine differing in its atomic weight by several units. Thus it seemed worth while to determine its atomic weight.

To test if the Iodine was present in the ore in the free state, 447 gms. of the ore were placed in a long tube and a gentle stream of air passed over it for 24 hours. A piece of starch paper was placed in the stream

which also had to pass through some Carbon Bisulphide. This method could have detected at least as small a quantity as $\frac{1}{50}$ mgm. of Iodine. No Iodine was detected although the ore was known to contain 1700 times this amount, showing that it is not, at any rate, given off at ordinary temperatures.

It was found that it was evolved on heating the ore to red heat. On the assumption that the Iodine was driven off entirely at a bright red heat, a preliminary analysis of the ore for this element was carried out in the following manner;

A hard glass tube containing 30 gms of the ore was heated in a furnace in a stream of air that was drawn through Carbon Bisulphide. When no further trace of Iodine was detected with fresh Carbon Bisulphide, the Carbon Bisulphide was collected in a flask fitted with a ground glass stopper. Nitrosyl sulphuric acid was added to oxidise any Hydriodic acid that may have been formed. The Carbon Bisulphide was then washed free from acid and a little Sodium Bicarbonate added. It was then titrated with a standard solution of Sodium Thio sulphate.

The analysis was repeated with various

grades of the ore with the following results :-

Ore	Weight taken.	$Na_2S_2O_3$ reqd.	% age Iodine
Grade I	30.00 gms	15.5 ccs	.0056
Grade II	11.84 "	.8 "	.0007
Grade III	30.70 "	3.2 "	.0011
Misced Grade I	28.08 "	5.8 "	.0022
Misced Grade II	10.30 "	2.15 "	.0022

The "misced grade I" contained 60 % of Grade I and, from the above table, only 38 % as much Iodine.

The last column shows that the Iodine was unevenly distributed throughout the ore. Further, as no Iodine was obtained by heating the following other radio active ores, pitchblende, thorianite and monazite sand, it seemed to indicate that the Iodine was present in Ceylon Thorite accidently and not by reason of any genetic relationship with Thorium.

The atomic weight of the Iodine was carried out by the synthesis of Palladious Iodide.

Purification of the Iodine.

Between 1 and 2 grams of Iodine dissolved in 10 litres of Hydrochloric acid were originally available for the research. The Iodine was removed in the first place by shaking up with Chloroform. The acid that had been treated in this way was subsequently treated with Nitrous acid and if a brown colouration appeared due to iodides having been oxidised to Iodine, the latter was removed by further treatment with Chloroform. The chloroform solution was then shaken with a solution of caustic potash in a separating funnel until the chloroform was free from Iodine. The caustic potash was then treated with Nitrous acid and chloroform and these operations were alternately performed with diminishing quantities of reagents until a solution of caustic potash only about 5 ccs. in volume containing all the Iodine was obtained. On acidifying with Nitrous acid nearly the whole of the Iodine was precipitated. It was filtered off on glass wool and the latter introduced into a glass tube where the wet Iodine was sublimed into a weighed glass tube connected by a ground glass joint.

To Pump
CS_2
CS_2
A
B
C
P_2O_5
H_2SO_4
$AgNO_3$

The Weight of the wet Iodine obtained was 1·09 gms.

A portion of this Iodine was tested in an α ray electroscope but no ionisation was detected.

The Iodine was dried and collected in a Guttmann weighing bottle in the apparatus shown in the sketch on the opposite page.

A slow stream of air was drawn through a solution of Silver Nitrate to remove HCl and H_2S, and dried thoroughly by passing through H_2SO_4 and then P_2O_5.

It was then passed over the wet Iodine and any small amount of Iodine that vapourized was caught in a solution of Carbon Bisulphide through which the air was drawn. The end of the long tube nearest the P_2O_5 bulb could be gently and evenly heated by means of an iron wire in an electrical circuit. The Iodine was thus distilled nine times during the ten days that it was in the long tube and was thus effectively freed from occluded moisture. A weighed bottle C fitted with stoppers D and joints A + B all of ground glass was introduced into the circuit. The Iodine was distilled into this bottle which was kept cool by immersion in a freezing solution. When this final sublimation was complete, the weighing bottle was removed, the glass stoppers inserted at A and B, and the bottle carefully wiped with a clean cloth.

It was allowed to stand in a dessicator for some time and then weighed in a balance easily read to $\frac{1}{20}$th milligram, whose weights had been calibrated to that accuracy.

The weighing bottle had originally been treated in the same manner before being weighed empty.

The efficiency of the above method of drying the Iodine was shown by a control experiment carried out with two samples of ordinary Iodine. The former was introduced into the long tube with about 2 ccs. of water whereas the latter was quite dry. The ratio $\frac{\text{Iodine}}{\text{Palladious Iodide}}$ agreed in the two cases to 1 part in 20,000.

The Palladious Chloride used was supplied in such a state of purity that it was perfectly soluble in a 1% solution of Hydrochloric Acid giving no trace of precipitate on prolonged standing. A stock solution was made up of such strength that 156.2 ccs. of it contained 1 gm. of Palladium. This solution was used throughout the whole series of experiments. All the water used was twice distilled, once over Sodium Carbonate to free any ammonia, when the middle portions only were used.

Method of Synthesis.

The weighed bottle containing the Iodine was immersed in a solution of Sulphurous Acid contained in a beaker of 1 litre capacity. The solution was prepared by passing Sulphur Dioxide from a syphon into pure water. The glass stoppers of the weighing bottle were removed by means of platinum wires, while immersed in the Sulphurous Acid. The bottle was then tilted so that the air inside was slowly displaced by the acid. The Iodine was then shaken out of the bottle and the latter removed by a glass rod. The bottle was carefully rinsed with water. The solution was stirred for several hours when all the Iodine went into solution and the latter was perfectly clear. The beaker was then floated in a larger one containing hot water and an excess of the calculated amount required by about 5 ccs. of Palladious Chloride run in.

The solution was allowed to stand for about 48 hours in a warm place and then filtered in a weighed Platinum Gooch crucible prepared with a layer of spongy Platinum. The precipitate was washed with hot water and then dried in a thermostatic oven at 66 °C till its weight was constant.

It was weighed as Palladious Iodide.

The crucible was then heated to red heat in a closed tube in a current of dry air so that the Iodine evolved could be recovered.

The loss in weight of the crucible due to the Iodine evolved gave an independent check on the estimation of the atomic weight.

Observations.

Material.	Weight of Iodine (in gms.)	Wt. of PdI_2 (in gms.)	Difference (Pd)	Loss in Weight (I)	At. Wt. of Iodine	
					from ratio $\frac{Pd}{PdI_2}$	By check I/PdI_2
Sample 1. Ordinary Iodine	·53240	·75625	·22385	·53020	126·9	126·3
" 2 " "	·69650	·98935	·29285	·69565	126·9	126·5
" 3 Thorite Iodine.	·44670	·62705	·18035	·44075	132·1	126·2
" 4 Thorite Iodine (3 Recovered).	·25920	·36810	·10890	·25800	127·0	126·4

Discussion.

The first two lines show the results of the control experiments with ordinary Iodine mentioned above. The experimental conditions throughout were made as similar as possible to those of the Thorite Iodine.

The weights of the Palladium after heating to red heat were consistently high as is shown by the low values obtained in the last column. It was attributed to slight surface oxidation of

the Palladium.

Of the four results with Thorite Iodine the last three agreed very well with those for ordinary Iodine. The high value, 132.1, for the first determination was thought to be due to the fact that the Iodine was not perfectly dry. This was quite possible because a small amount of Iodine was inevitably lost in the drying process and it was imperative, in view of the fact that only about half a gram of Iodine was available for the research, not to carry the process too far. This only affected the first determination for, after that, the Iodine was not allowed to get wet in the free state.

Conclusion.

The Iodine occurring in Ceylon Thorite does not differ appreciably in atomic weight from ordinary Iodine and its occurrence in that ore is probably accidental

Part III.

The Parent of

Actinium.

The Parent of Actinium.

Discussion.

A discussion of the problem is shown in the enclosed reprint from the Proceedings of the Royal Society, A. Vol. 94. pp. 384 to 392.

The Separation of Eka-tantalum from Pitchblende.

A comparison of the properties of the compounds of niobium and tantalum, and the methods of separating these elements, led to the following process being tried, first on uranium-X, to ascertain whether it was capable of separating uranium X_2, the isotope of eka-tantalum, from uranium X_1, the isotope of thorium. When this was found to be successful, the method was tried first on small and then on large amounts of pitchblende. The specimen of pitchblende used was from a very fine block of practically pure Indian pitchblende, found to consist of 86 per cent U_3O_8, 11·9 % PbO, 1·9 % ThO_2 and ·6 % SiO_2.

The material was heated in a quartz tube in a current of dried air, charged with the vapours of carbon tetrachloride by passing it through that liquid, kept at a few degrees below its boiling point. It was expected that, under these circumstances, an element resembling tantalum

would volatilise at a lower temperature than the other pre-emanation disintegration products in the mineral. In a trial with uranium oxide and tantalic acid, placed side by side in two boats in the tube, it was found that, at a temperature in the neighbourhood of visible red-heat, at which the tantalic acid volatilised freely, the uranium did not volatilise at all. The oxide, in fact, gained weight through absorption of chlorine.

Using a preparation of uranium X, it was found that, even at a temperature below a visible red-heat, a considerable part of the uranium X_2 volatilised. The boat containing the uranium-X preparation was removed from the furnace, and measurements of the penetrating β rays started as rapidly as possible. The quartz boat was chilled externally by water after removal from the furnace. The curves shown in the reprint p. 393 indicate the growth of the penetrating rays, due to uranium-X_2, after removal from the furnace. For the curve marked A the temperature was just visible red-heat, and for that marked B just below visible red-heat. The results indicate that, even in the very short period of uranium-X_2, a large proportion of it is removed by this treatment. It follows, therefore, à fortiori, that the method should be capable of

removing the predicted element, since it is isotopic with uranium-X_2, and must have a very extended period of average life.

In the experiments with pitchblende, it was found that only a very small part of the material volatilised at temperatures in the neighbourhood of visible red-heat. The sublimate had a high α and β activity, the former being for the most part due to polonium, as shown by its subsequent history, and the latter to radium-E, as shown by its absorption coefficient. But none of the pre-emanation members could be detected in the sublimate, so that there was nothing present which would interfere with the active deposit test for the presence of actinium.

In the main experiment 470 gms. of finely powdered pitchblende were used. It was heated in the carbon tetra chloride stream just below visible red-heat for 22 hours, the boat containing the material being several times removed during the sublimation, and the contents well mixed before it was replaced. In this operation the material gained 25 gms in weight through absorption of chlorine, and the sublimate obtained weighed 5 gms. The sublimate was put back in an empty boat, and resublimed, as before, for four hours.

The second sublimate weighed ·28 gm. It was washed into a platinum capsule with hydrochloric acid, and dried on the water bath. It will be termed Preparation I, the date of preparation being March 18, 1915.

The part not sublimed in the two processes described was re-sublimed, as before, at the same temperature, but for a further period of 90 hours. The considerable amount that sublimed was re-sublimed as before, and a second preparation, weighing 2·45 gm. obtained. It was dried on a crucible lid and mounted in a shallow lead tray, a platinum wire being fixed to make contact between the preparation and the lead tray. It is termed Preparation II, the date of preparation being March 25th 1915.

It was thought that Preparation I would contain most, if not all, of the eka-tantalum if present in the mineral, and that Preparation II would give an indication whether the separation in the first operation had been complete or not.

Method of Testing for the Presence of Actinium.

The preparations were kept in a dessicator, and tests for the presence of actinium carried out at intervals. Owing to the exigencies of the time,

the intervals elapsing between the tests were rather irregular, and in one case over a year elapsed between successive tests. The preparation was covered with a metal plate, insulated by a rubber or mica washer and connected to the negative pole, the plate being connected with the positive pole of the 220 volt direct current mains. Equilibrium for the active deposit of actinium is attained practically in four or five hours, and the exposure was usually overnight. In a few cases of shorter exposure the necessary correction was supplied from the table of the decay of the actinium active deposit given in Makower and Geiger's 'Practical Measurements in Radio activity': p. 147. After exposure the plate was removed as quickly as possible after the disturbance caused by the opening of the electroscope had subsided and continued for four or five hours. The decay curve over this period was plotted and the constant determined from the curve. If the activity is due to actinium the activity decays exponentially, - after an initial somewhat slower rate of decay extending over the first few minutes caused by actinium-C of period 3.1 minutes, - with the period of actinium-B, 51 minutes. The character of the curve shows at once whether it is due to actinium, for

although the period of radium - B, 38.5 minutes, is not very greatly different from that of actinium B, the active deposit could not possibly be mistaken for that of radium, since the latter would show the large rapid initial decay due to radium - A.

Observations on the Growth of Actinium.

Preparations I and II, when prepared, gave completely negative results when tested as described during the period covered by the first few weeks from preparation. Not the slightest detectable growth of actinium has occurred in Preparation I in 2.5 years, though it was thought that the main quantity of eka-tantalum would be concentrated in it. In Preparation II there was a continuous growth of actinium, so that after 2.6 years from preparation, the leak in the electroscope due to the active deposit of actinium amounted initially to over 10 divisions per minute. This is 20 times as much as could be with certainty detected, and 10 times as much as could be with certainty characterised as due to actinium.

The decay curve of a measurement of this preparation, 2.6 years from preparation, is shown on p. 396. The value of the period

as calculated from the slope of the logarithmic decay curve is 53.5 minutes, that of actinium B being 52.1 minutes, and the curve is that to be expected of a pure actinium active deposit.

On p. 397 is shown the growth of actinium with time for this preparation. It indicates the expected initial period of retardation due to the members radio-actinium of period 28 days, and actinium X of period 16.4 days, and after that a regular increase with time. The quantitative estimation of actinium is of course very much more uncertain and difficult than that of radium, and, indeed, there has been little or no work practically attempted yet in this field, and it may be doubted whether a really accurate method applicable to very minute quantities is yet possible. No great consistency is to be expected from the method described, for the solid preparation probably varies somewhat in emanating power. For this reason it would be premature to build much upon the precise form of the curve, and the indication that it gives of an increase in the rate of growth of actinium with the lapse of time, and an increase of slope in the later measurements. Not enough measurements have been taken, and the method is too uncertain to justify

the conclusion that this indicates the existence of intermediate bodies between the eka-tantalum and the actinium. For we know, from the α and β-ray change rules, that three, if any, such intermediate bodies must intervene, and this is not very probable.

Thus, contrary to expectation, instead of the main part of the parent of actinium being in the first sublimate obtained, it is, so far as can be seen, wholly contained in the second. The second preparation was obtained by merely continuing the process of sublimation at the same temperature as the first for a further 90 hours after an initial 22 hours, so that it was surprising that the whole of the eka tantalum should have appeared in the second preparation. The probable explanation is that the eka tantalum does not commence to volatilise until the material has become saturated to a certain point with chlorine. In the case of the large mass of material used, this preliminary to the process would of necessity take a considerable time.

Theory of the Growth of Actinium from Eka-tantalum.

The calculations whereby the theoretical curve

was obtained is shown in the paper on pp. 399 and 400.

Summary.

(1.) Uranium X_2 can be separated from Uranium X_1 by sublimation in a current of air charged with vapours of Carbon tetra chloride, at a temperature below visible red heat.

(2.) 470 gms of a very pure Indian pitchblende were similarly treated, in the expectation of removing eka-tantalum, isotopic with uranium X_2 and giving actinium in an α ray change of long period.

(3) The preparations so obtained were initially free from actinium, but one of them has produced it continuously with the lapse of time.

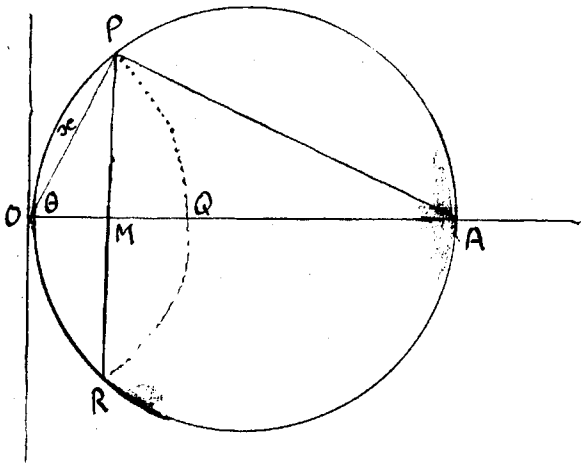
(4) A direct comparison of the amount of actinium in this preparation after the lapse of 2·5 years with that in the original pitchblende showed that it was equal to that in about ·25 gms.

(5) On the assumptions that eka-tantalum and actinium are both long-lived, that no intermediate bodies intervene between them, and that the preparation contained the whole of the parent of actinium in the original mineral, the period of average life of actinium was calculated to be 5000 years.

(6) The work was undertaken to test and confirms the view that the parent of actinium occupies the eka tantalum place in the Periodic Table, and gives actinium in an α ray change of long period.

2.

"The Ionisation Produced at an External Point By a Sphere of Uniformly Radio-active Matter."



Let I = ionisation at O, due to unit volume situated at P, distant x from O (when $\mu = 0$).

I_0 = ionisation at O due to unit volume at O.

Area PQR $= 2\pi x h$ (where h = ht. of spherical cap i.e. MQ)

$$h = OQ - OM$$
$$= x - x\cos\theta.$$
$$\cos\theta = \frac{x}{2r}$$
$$\therefore h = x\left(1 - \frac{x}{2r}\right)$$

$\therefore$ Area of $PQR = 2\pi x^2\left(1 - \frac{x}{2r}\right)$.

$x^2 I$ = ionisation at P, [when $\mu = 0$]

$x^2 \frac{I}{I_0} = e^{-\mu x}$ for unit volume at P.

$= e^{-\mu x} \cdot 2\pi x^2\left(1 - \frac{x}{2r}\right)$ for spherical cap of unit thickness going thro' P

$$\frac{I}{I_0} = \int_{x=0}^{x=2r} e^{-\mu x} \cdot \frac{2\pi x^2}{x^2}\left[1 - \frac{x}{2r}\right] dx \qquad \text{for the whole sphere.}$$

$$= 2\pi \int_{x=0}^{x=2r} e^{-\mu x}\left[1 - \frac{x}{2r}\right] dx .$$

$$\int_{x=0}^{x=2r} e^{-\mu x}\left(1 - \frac{x}{2r}\right) dx = -\frac{1}{\mu} e^{-\mu x}\left(1 - \frac{x}{2r}\right) - \int \frac{1}{\mu} e^{-\mu x} \cdot \frac{1}{2r}$$

$$+ \frac{1}{2r\mu^2} e^{-\mu x} \Big\|_{x=0}^{x=2r}$$

$$= \frac{1}{2\mu^2 r} e^{-2\mu r} - \left[-\frac{1}{\mu} + \frac{1}{2\mu^2 r}\right]$$

$$= \frac{1}{\mu} - \frac{1}{2\mu^2 r}\left[1 - e^{-2\mu r}\right]$$

$$= \frac{1}{\mu} - \frac{1}{2\mu^2 r}\left[1 - 1 - 2\mu r + \frac{4(\mu r)^2}{2} - \frac{8(\mu r)^3}{6} + \frac{16(\mu r)^4}{24} - \frac{32\mu r^5}{120} + \ldots\right]$$

$$= r\left[1 - \frac{2}{3}V + \frac{1}{3}V^2 - \frac{2}{15}V^3 + \ldots\right] \quad \text{where } V = \mu r.$$

Thus $\frac{I}{I_0} = 2\pi r\left[1 - \frac{2}{3}V + \frac{1}{3}V^2 - \frac{2}{15}V^3 + \ldots\ldots\right]$

In a given sphere containing radio active material uniformly distributed throughout, the following additional data was observed which enabled the problem to be solved:

Volume of sphere = 220 ccs. (giving radius r)

Weight of preparation = 273·15 gm. (giving density, D)

$\frac{\mu}{D} = \cdot 056$ (giving μ and μr)

3.

The Acquired Activity of Diamonds.

The Acquired Activity of Diamonds

In a paper* by Sir Wm. Crookes on the activity of diamonds that have been exposed to Radium salts, he gives evidence to show that the activity might have been of another type than that of the usual active deposit.

At Professor Soddy's request he sent an exposed diamond, called No. 17 in the above paper, to our laboratory for a further examination. The results obtained did not agree with those published in his paper.

β- Activity

The β activity of the diamond, said to be sufficient to discharge an electroscope in 5 seconds, and further said to be constant over two years, was found to be so small that it was not detectable with certainty in a specially delicate β-ray electroscope.

α- Activity

The α activity, said to be very large was found to be less than 20 divisions a minute in an α- electroscope. This activity was

* Trans. Roy. Soc. 16th Dec. 1914.

not removed by treatment with hot strong hydrochloric acid – in accordance with Crookes' observations.

Luminosity.—

The diamond was said to be brightly luminous in the dark owing to its radio activity. but its luminosity was not sufficient to make it seen even after half an hour spent in the dark to raise the sensitiveness of the eye.

Conclusion

It was concluded that the "acquired" activity Crookes obtained was that due to the usual active deposit and that his violent chemical treatment removed most of the activity in spite of his statements to the contrary.

4.

The Separation of Actinium

From

Lanthanum.

The Separation of Actinium from Lanthanum.

A series of experiments were carried out to test compounds, other than the double nitrates of magnesium or manganese, for concentrating actinium in lanthanum.

Much preliminary work was carried out on the chemical behaviour of meso thorium 2 in the belief that it would afford an indication of how its isotope actinium would react, before it was found out that many abnormal results were got with mesothorium 2 alone that could not be repeated with actinium and lanthanum. This was doubtless due to the minuteness in quantity of the meso thorium 2 with consequent abnormal behaviour due to adsorption.

Expt. 1. In a neutral solution containing Thorium and mesothorium 2, it was found that a complete separation was effected by the addition of Sodium Azoimide. The thorium was precipitated and the mesothorium 2 retained in solution.

Expt. 2. To a neutral solution of $K\,Mn\,O_4$ containing mesothorium 2 a few drops of alcohol were added. $K_2\,Mn\,O_3$ was precipitated and it brought down 81 % of the mesothorium 2.

The mesothorium 2 was estimated in the usual way by the ionisation it produced with a γ ray electroscope.

Expt. 3. Sodium peroxide was added to the K_2MnO_3 but only 65% could be got again into solution.

Expt. 4. Hot concentrated hydrochloric acid was found to dissolve K_2MnO_3. On adding a trace of a thorium salt and then precipitating out with ammonia 95% of the meso thorium 2 was precipitated and the manganese was kept in solution.

Expt. 5. The reduction of $KMnO_4$ with alcohol was repeated, this time in the presence of Lanthanum as well as mesothorium 2. K_2MnO_3 was precipitated as before but no mesothorium 2 came down with it.

Expt. 6. In view of the evident difference of behaviour of the manganite reaction when lanthanum is present, experiments were commenced to ascertain the conditions of the reaction required to separate lanthanum and mesothorium 2. It was found that $MgSO_4$ was valuable in the solution to prevent the accumulation of KOH.

Expt. 7. Separation of Mesothorium 2 and Lanthanum.

A weighed quantity of Lanthanum nitrate was added to a neutral solution containing a known amount of mesothorium 2 free from thorium. A little $MgSO_4$ was added to keep the solution neutral. A solution of $KMnO_4$ was added and partly reduced by adding four drops of alcohol. The brown ppte. (K_2MnO_3) formed contained all the mesothorium 2.

The permanganate was then completely reduced by alcohol and filtered. Both precipitate and filtrate were inactive.

The filtrate was made alkaline with NH_3. The ppte. formed was filtered, ignited and weighed. It was then dissolved in acid, nearly neutralised and Oxalic acid added. Under these conditions lanthanum is precipitated and manganese is not. A ppte. formed which when filtered, ignited and weighed was found to be of the same weight as the previous one. This showed that the filtrate originally contained lanthanum and 65% by weight was recovered in this way.

The first ppte. of K_2MnO_3 was treated with warm dilute HNO_3 and HCl. Two thirds of the mesothorium 2 went into solution but on adding NH_4OH, & filtering, igniting and weighing

the precipitate formed, there was found to be only 4 milligrams weight there, and this must have been mainly K_2MnO_3.

Summary. When $KMnO_4$ is reduced in the presence of mesothorium 2, lanthanum and magnesium sulphate, all the mesothorium 2 is precipitated with the K_2MnO_3 and at least 65% of the lanthanum goes into the filtrate.

Expt. 8. A solution of lanthanum nitrate was added to a solution containing mesothorium 1 in equilibrium with mesothorium 2. The lanthanum together with the mesothorium 2 was precipitated out with NH_4OH. The ppte. was filtered and then dissolved in a very small quantity of acid. This solution was divided into two portions.

(1). The solution was carefully neutralized and then some solid K_2MnO_3, which had been obtained by the usual reduction of $KMnO_4$ with alcohol, was added and shaken in the solution. It was found that 20% of the mesothorium 2 adhered to the K_2MnO_3 on filtering.

(2). The second portion was nearly neutralised with caustic soda, $KMnO_4$ was added and then some alcohol. The liquid first became clear reddish brown, and then a precipitate formed which contained no mesothorium 2.

Expt. 9. The effect of reducing $KMnO_4$ with NaN_3 in neutral solution in presence of mesothorium 2 was tried. The azoimide precipitated 74% of the mesothorium 2.

Expt. 10. Mesothorium 2, free from all other radio active bodies was prepared, the thorium being separated by H_2O_2. A strong solution of $MnCl_2$ was added to the solution neutralised with NH_4OH. $KMnO_4$ was added drop by drop. When a permanent ppte. formed it was filtered and its β activity measured. A second ppte. was got by adding more $KMnO_4$ and its activity measured. H_2O_2 in excess was objectionable owing to its oxidising properties on the precipitates and no consistent results were got by this fractional precipitation.

Expt. 11. Experiments were carried out using Lanthanum and Actinium with Mesothorium 2 as an indicator of the behaviour of the inactive actinium. KCN was added to a solution containing those three substances. They were all found to be precipitated quantitatively.

Expt. 12. Potassium Bichromate was found to ppte. lanthanum readily and in the first experiment all the actinium was precipitated too. It was repeated

however, this time the $K_2Cr_2O_7$ was added cautiously so that fractional precipitation occurred.
The following observations were recorded.

	Lanthanum		Activity	% meso-thorium 2	Lanthanum / mesothorium 2
	Weight	%	(divs. per min.)		
1st Fraction	·0396 gms.	18·7	·5	1·0	18·7
2nd "	·0488 "	22·9	11·3	21·9	1·0
3rd "	·0671 "	31·4	26·2	50·8	·6
4th "	·0576 "	27·0	13·5	26·3	1·0
Total.	·2133 "	100·0	51·5	100·0	

It was seen that by the cautious addition of Potassium Bichromate, 18·7% of the lanthanum was removed almost free from mesothorium 2.

Expt. 13. A quantity of Lanthanum was precipitated out of a solution containing mesothorium 1 in radio active equilibrium with mesothorium 2. It was dissolved in sulphuric acid and then precipitated out fractionally as the double sulphate of lanthanum and potassium by the cautious addition of potassium sulphate.
Four fractions were obtained and the β and γ activities of each measured. The weight of lanthanum in each fraction was estimated by dissolving the double sulphates in the

minimum quantity of acid, precipitating out by NH_3, igniting and weighing.

Number of Fraction	β. activity corrected for decay	γ. activity corrected for decay	Weight of lanthanum oxide	Ratio $\frac{\text{Wt. of La}}{\beta \text{ act.}}$	Ratio $\frac{\text{Wt. of La}}{\gamma \text{ act.}}$
1	23·2	3·25	113·5 mgms	·41	·41
2.	17·9	2·43	98·1 "	·45	·45
3.	30·0	4·26	161·3 "	·44	·43
4.	11·6	1·45	55·0 "	·39	·39

The constancy of the figures in the last two columns showed that this method was not suitable to concentrate lanthanum in mesothorium 2.

Expt. 14. Potassium Permanganate was fractionally precipitated by Alcohol in presence of actinium, lanthanum and magnesium sulphate.
Mesothorium 2 that had been freed from all other radio active bodies was added as an indicator. Four fractions were obtained and they were placed in tin boxes covered with aluminium foil of thickness ·00073 cms.
The β activity of each fraction was measured immediately indicating the distribution of the mesothorium 2. Four months later when the actinium series came into equilibrium the β activities

were again measured indicating the distribution of the actinium. The tins were then opened and analysed for lanthanum.
The following observations were recorded.

Number of Fraction.	% age Ionisation.		Weight of Lanthanum present.	Ratio $\frac{\text{wt. of La.}}{\text{Activity of Ac.}}$
	due to mesothorium 2	4 months later due to actinium		
1	9·3	9·1	6·2 mgms.	6·8
2	19·8	20·6	11·1 "	5·4
3	32·6	32·1	14·8 "	4·6
4	38·3	38·2	16·3 "	4·3

The close agreement of columns 2 and 3 furnished further evidence of the chemical identity of mesothorium 2 and actinium.
From the last column it is seen that a slight concentration of actinium in lanthanum was effected by this method.